Influence of abutment material on the gingival color of implant-supported all-ceramic restorations: a prospective multicenter study

Key words: cad-cam technology, implant abutments, peri-implant soft tissue, spectrophotometer

Abstract

Purpose: The aim of this clinical research on implant-supported restorations is to analyze, through spectrophotometric digital technology, the influence of the abutment material on the color of the peri-implant soft tissue.

Material and methods: Twenty patients received an endosseous dental implant in the anterior maxilla. At the time of each definitive prosthesis delivery, an all-ceramic crown has been tried on gold, titanium and zirconia abutment. After the insertion of each single abutment, the peri-implant soft tissue color has been measured through a spectrophotometer. Also, the thickness of the facial peri-implant soft tissue was measured at the level of the implant neck through a caliper. A specific software has been utilized to identify a specific tissue area and to collect the data before the statistical analysis in Lab color space. The normality of the quantitative variables was verified by means of the Shapiro–Wilk test. Simple linear correlation between quantitative variables was evaluated by using Pearson’s coefficient. The results on the performance of the abutment materials with regard to the color measurements and the overall measurement ΔE were described by computing the least-square means. The significance of differences among types of abutment was verified by means of the Scheffe test for multiple comparisons.

Results: For all the abutments used, the color of the peri-implant soft tissue appeared to be significantly different from the one of the contra-lateral tooth (ΔE > 8.5). Significantly higher (P < 0.05) difference were present with the use of titanium abutments (11 ± 0.4) when compared with the results of gold (8.9 ± 0.4) and zirconia (8.5 ± 0.4) abutments. No correlation has been demonstrated between soft tissue thickness and degree of color difference (P > 0.25).

Conclusions: Within the limitation of the present study, the peri-implant soft tissue color appears to be different from the soft tissue color around natural teeth, no matter which type of restorative material is selected. When titanium abutment was selected, significantly higher differences were present than those obtained with gold or zirconia abutments. The thickness of the peri-implant soft tissue did not appear to be a crucial factor in the abutment impact on the soft tissue color.

The preservation or reproduction of a natural mucogingival architecture surrounding dental implants placed in the anterior maxilla is esthetically challenging for the restorative dentist, particularly when patients present with a high lip line when smiling. The challenge arises from the loss of muco-gingival tissue as a result of bone loss after extraction of traumatically injured or periodontally compromised teeth, or is due to a traumatic surgical extraction or congenital defects (Buser et al. 2004).

The selection of a dental implant system that allows a proper biological response of the hard and soft tissues, represents the first step for the achievement of an adequate esthetic result (Sykaras et al. 2000). Besides, a proper surgical technique, implant positioning and soft tissue management are necessary for a natural outcome (Choquet et al. 2001; Kan et al. 2003; Grunder et al. 2005; Quirynen et al. 2007). Finally, the selection of the proper prosthetic solution, which is often overlooked, contributes significantly in the achievement of a proper shade and shape of the gingival tissue [Bichacho & Landsberg, 1997; Tarnow & Eskow 1996]. The utilization of customized emergence profiles and abutments is critical for the achievement of proper esthetic results (Gallucci et al. 2004).

Most recently, all-ceramic restorations have become increasingly popular for restoring teeth and implants. The advantages of all-ceramic restorations cemented over metal abutments are questionable, especially when the abutment choice is for a highly translucent heat-pressed
ceramic restoration [Nakamura et al. 2002]. All-ceramic abutments, made of aluminum oxide or yttrium-stabilized zirconium oxide, have been produced in an effort to overcome this esthetic problem [Prestipino & Ingar 1993; Wohlgend et al. 1996; Heydeck et al. 2002; Rompen et al. 2007].

The esthetic benefit of ceramic abutments over metal abutments has been well documented in a recent clinical study by [Jung et al. 2008]. Anyway, increased thicknesses of alumina and zirconium oxide could compromise the esthetic result due to an increased opacity and reduced translucency [Hefferman et al. 2002a, 2002b]; therefore, the benefit might be controversial.

The presence of different abutment closer to the soft tissue might affect the esthetic appearance of the peri-implant soft tissue and alter its color and appearance. In a recently published study by [Jung et al. 2008], with the utilization of titanium or gold abutment with PFM Crown or aluminum oxide abutment with all-ceramic crown, clinically noticeable differences were present in comparison with the contra-lateral tooth; all-ceramic restorations revealed a significantly better color match to the un-restored neighboring teeth than porcelain-fused-to-metal restorations on titanium or gold abutments.

The purpose of this clinical trial on implant-supported restorations is to analyze, through spectrophotometric digital technology, the influence of the abutment material on the color of the peri-implant soft tissue. Moreover, the correlation between soft tissue thickness and digital evaluation will be analyzed in order to verify possible esthetic implications for the utilization of different types of abutment material related to different clinical situations.

Material and methods

Twenty patients have been included in this prospective multicenter study. All patients have been treated at the University of Padova Dental School and at Dental Clinic of Biomedical Sciences Institute, St. Paul Hospital, University of Milan, Italy. The study protocol was approved by the University of Padova and Milan Institutional Ethics Committees. Informed consent was obtained from all subjects.

Each single patient received an endosseous dental implant (Osseospeed 4.08, Astra Tech Dental Implant, Astra Tech AB, Molndal, Sweden), which has been placed in the anterior maxilla [area from tooth 1.5 and 2.5].

To be included in the study, all patients presented: (i) controlled periodontal condition [no PPD index superior to 4 mm, no bleeding on probing and plaque index inferior to 20%]; (ii) no active intraoral or systemic disease; (iii) healed single edentulous site; and (iv) tooth contralateral to the placed implant: the natural tooth had to be present, vital and not restored.

Exclusion criteria were: (i) patients with systemic diseases [such as heart, coagulation and leukocyte diseases or metabolic disorders]; (ii) history of radiation therapy in the head and neck region; (iii) current treatment with steroids; (iv) neurological or psychiatric handicap that could interfere with good oral hygiene; (v) immunocompromised status, including infection with human immunodeficiency virus; (vi) severe clenching or bruxism; (vii) smoking habit (> 15 cigarettes/day); (viii) drug or alcohol abuse; and (ix) inadequate compliance.

A two-stage surgical technique and no additional soft or hard tissue graft were planned for all the implants. All implants were submerged and all parts of the defects were covered by mucosal tissue. Removable prostheses or provisional fixed bridges were adjusted.

Four months after implant placement, surgical re-entry occurred, implant stage 2 was performed by the same operator and a trans-mucosal healing abutment (Healing Abutment 3.5/4.0, Astra Tech Dental Implant) was inserted [Time 0].

Two weeks after surgical re-entry, an implant-level impression was taken for the fabrication of a screw-retained temporary restoration [Time 1]. The provisional restoration was inserted 1 week after implant level impression. After 8 weeks of soft tissue conditioning by means of the provisional restoration, a definitive implant level impression was taken, a precise record of the soft tissue dimensions [Time 3] was recorded. The pick-up impression coping was modified by adding a self-polymerizing resin (Duralay, Chicago, IL, USA) in order to reply the emergence profile of the provisional restoration in the definitive cast (type IV dental stone, New Fujif-Rock, GC Corp., Tokyo, Japan). The thickness of the facial peri-implant soft tissue was measured at the level of the implant neck through a caliper (Iwanson Decimal Caliper, Asa Dental spa, Lucca, Italy) (Figs. 1 and 2). The peri-implant mucosa was replicated by using a light-consistence siliconic material around the implant analog before the dental stone application so that an eventual inaccuracy of the soft tissue reproduction steps could be reduced at least.

The definitive prosthesis was an implant-supported single crown cemented on a customized abutment. One full coverage restoration was fabricated for each single implant with the utilization of a zirconia coping (Lava, 3M ESPE, Seefeld, Germany) and feldspathic porcelain stratification (Ziro X veneering ceramic, Wieland Dental + Technik GmbH & Co. KG, Pforzheim, Germany).

The customized abutment was the variable of the present study and three different materials have been utilized: titanium, gold-alloy and zirconia as shown in Table 1. The facial and interproximal margin level were kept 1 mm subgingival while the palatal margin was left equigingival. CAD-CAM technology (WizBlade, Nextec Technologies 2001 Ltd., Tirat HaCar mel, Israel) was used to create the same morphology for all the 3 types of abutments using a milling machine (MIKRON HSM 400U ProdMed, Angie Charmilles International SA, Geneva, Switzerland).

Fourteen weeks after implant stage 2 [Time 4], the temporary restoration was removed and definitive customized abutments were screwed [Ratchet Wrench, Astra Dental Implant]. The definitive all-ceramic crown (Lava, 3M ESPE) was temporarily placed on the abutment with a
the soft tissue was noticed, 10 min were left
tive prosthesis from the final one, no pressure on
Even if without altering the shape of the defini-
tion was unscrewed and the second one was
immediately after the first color measurement, the all-
ceramic restoration was removed, the first abut-
ment was positioned in the same manner of the first one.

Table 1. Abutment type

<table>
<thead>
<tr>
<th>Abutment type</th>
<th>Abutment material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Cast-to abutments 3.5/4.0 (Astra Tech Dental Implant) Keramit Eco LF, Micro Fine Grain Alloy (Au 57%, Pd 10.6%, Ag 29.2%) (NobilMetal S.p.A., Villafranca d’Asti, Italy)</td>
</tr>
<tr>
<td>Type 2</td>
<td>Titanium abutment: platform 3.5/4.0 (Astra Tech Dental Implant)</td>
</tr>
<tr>
<td>Type 3</td>
<td>Zirconia abutment: platform 3.5/4.0 (Astra Tech Dental Implant)</td>
</tr>
</tbody>
</table>

The significance level was fixed at 0.05, and all tests were two tailed. All the analyses were performed using the SAS statistical software rel. 9.1 (SAS Institute, Cary, NC, USA).

Fig. 2. Correspondent occlusal view of the dental implant and the facial peri-implant soft tissue.

Fig. 3. Titanium abutment screwed into position.
Results

The peri-implant soft tissue color was different from the soft tissue color around natural teeth, no matter which type of restorative material was selected (Table 2). Measurements relative to all the abutments were above the critical threshold of ΔE 3.7 for intraoral color distinction by the naked eye. When the crown was placed over the abutment, the ΔE mean value between the peri-implant soft tissue and the contra-lateral gingival tissue was similar for gold and zirconium abutment (8.9 and 8.5, respectively), but it was significantly greater with the titanium abutment (11).

Table 2. Estimated least square mean ± standard errors (SE) and 95% confidence intervals (95% CI) of ΔE by abutment materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean ± SE</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>8.9 ± 0.4</td>
<td>8.1–9.7</td>
</tr>
<tr>
<td>Titanium</td>
<td>11 ± 0.4</td>
<td>10.2–11.9</td>
</tr>
<tr>
<td>Zirconium</td>
<td>8.5 ± 0.4</td>
<td>7.6–9.3</td>
</tr>
</tbody>
</table>

Different superscript letters indicate significantly (P<0.05) different mean values (Scheffe’s test for multiple comparison).

The calculated Lab (L, a, b) values of the measured areas around abutments and natural teeth were summarized on Table 3. For each feature, natural teeth mean values were significantly higher than those of the different types of abutment. In addition, gold and titanium abutments provided no significantly different mean values both for L and b color measurement, while titanium abutment always provided lower mean values. For the a color measurements, no differences were evident among the three types of abutment. Gold, titanium and zirconia abutment measurements were significantly different (P<0.001) from contra-lateral teeth (control sites) measurements.

Calculated Lab values of different abutments with correspondent 95% CI are reported in Fig. 7; control sites were considered as reference. All the differences evaluated by using paired data were statistically significant, as shown by 95% CIs (zero value not included). Fig. 7 also showed that titanium abutment exhibited worse color performances than gold and zirconium abutments. The zirconia results were likely to achieve the best color matching with natural teeth, but the differences with gold performance were never statistically significant.

To verify the role of soft tissue thickness on the color measurements with the different abutment types, a stratified analysis was performed by dichotomizing the thickness on 2 mm (thin ≤ 2 mm; thick > 2 mm). Seven patients were included in the “Thin” group and the other 13 patients made up the “Thick” group, respectively. The ΔE mean value did not depend on the soft tissue thickness (Table 4), and thickness might only relate to the a*b color aspect (Table 5).

Discussion

The present study evaluated the color-change effect on marginal peri-implant soft tissue of all-
ceramic restorations based on zirconium oxide, gold-alloy and titanium abutments. The pecu-
liarity of this trial was that measurements were performed for all three abutment materials in 
each patient; therefore, important patient-related and material-related biases were avoided. More-
over, different from previous studies, only one type of crown was utilized, relating the results 
only to the abutment variable.

In accordance with the data available in the international literature by [Sailer et al. 2009] and 
[Zembic et al. 2009], the results of the present study showed a significant difference between 
the color of the peri-implant soft tissue and the color of the gingival around natural teeth no 
matter which type of prosthesis is used. As described on Table 2, ΔEs were always higher 
than the critical threshold of 3.7 [Johnston & Kao 1989]. This value, described as higher value for 
color matching between natural teeth and re-
stored teeth, might have only a relative impact on the analysis of the soft tissue but represent the 
most reported reference in the literature [Ishikawa et al. 1988; Jung et al. 2008; Lops et al. 2008; Romeo et al. 2008]. Other values reported 
in the tooth color matching literature are even 
lower [Douglas, 1997; Douglas & Brewer, 1998]. The absence in the literature of a reference for 
soft tissue color matching may represented a 
limitation in the analysis of present results, but 
the ΔE values obtained are significantly higher than the reported color differences between the 
soft tissues of contra-lateral natural teeth, which were within 2.7 [Zembic et al. 2009].

As described on Table 3, significantly different 
mean values have been found between titanium on one side and gold and zirconia on the other 
side. While no differences were present in the 
color performance of gold and zirconium oxide 
abutments, the color of the soft tissue around 
titanium abutment was significantly more different from the gingival color around natural teeth.

In addition, all the single values (L*, a*, b*) 
were different from the values obtained around 
natural teeth. Among the different type of abut-
ments, no significant differences were present in 
considering the red and green scale of a values, 
confirming a trend already reported in the litera-
ture [Hermann et al. 2001]. In the analysis of L* 
and b* values, significantly differences were pre-
sent among the abutment. The peri-implant soft 
tissue around zirconium oxide abutments ap-
peared to be significantly closer to the color of 
natural teeth gingival than titanium and gold 
abutment provided interposed results. Also, 
[Jung et al. 2008] noticed clinically gingival color 
differences between around peri-implant soft tis-
sue in comparison with the contra-lateral tooth. 
Nevertheless, their results suggested that all-
ceramic restorations on aluminum oxide abut-

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**Table 3. Estimated least square mean ± standard errors (SE) of Lab values: measured areas around abutments and natural teeth by abutment materials**

<table>
<thead>
<tr>
<th></th>
<th>Gold</th>
<th>Titanium</th>
<th>Zirconium</th>
<th>NT</th>
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</thead>
<tbody>
<tr>
<td>L*</td>
<td>47.1 ± 0.6</td>
<td>45.6 ± 0.6</td>
<td>48.1 ± 0.6</td>
<td>52.9 ± 0.6</td>
</tr>
<tr>
<td>a*</td>
<td>22.1 ± 0.5</td>
<td>21.5 ± 0.5</td>
<td>22.9 ± 0.5</td>
<td>25.9 ± 0.5</td>
</tr>
<tr>
<td>b*</td>
<td>14.9 ± 0.3</td>
<td>13.9 ± 0.3</td>
<td>15.4 ± 0.3</td>
<td>18.4 ± 0.3</td>
</tr>
</tbody>
</table>

Different superscript letters indicate significantly different mean values.

**Table 4. ΔE mean values and standard errors (SE) by soft tissue thickness and abutment materials**

<table>
<thead>
<tr>
<th>Soft tissue thickness (mean ± SE)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 2 mm (7 pt)</td>
<td>&gt; 2 mm (13 pt)</td>
</tr>
<tr>
<td>Gold</td>
<td>8.6 ± 1.4</td>
</tr>
<tr>
<td>Titanium</td>
<td>9.5 ± 1.4</td>
</tr>
<tr>
<td>Zirconium</td>
<td>7.5 ± 1.4</td>
</tr>
</tbody>
</table>

**Table 5. Correlation coefficients between soft tissue thickness (mm) and the difference for the Lab values of the measured areas around abutments and natural teeth or ΔE, by abutment materials**

<table>
<thead>
<tr>
<th></th>
<th>Gold</th>
<th>Titanium</th>
<th>Zirconium</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔL</td>
<td>0.2 (0.38)</td>
<td>-0.06 (0.81)</td>
<td>-0.04 (0.87)</td>
</tr>
<tr>
<td>Δa</td>
<td>-0.3 (0.19)</td>
<td>-0.26 (0.26)</td>
<td>-0.2 (0.38)</td>
</tr>
<tr>
<td>Δb</td>
<td>-0.45 (0.05)</td>
<td>-0.4 (0.08)</td>
<td>-0.4 (0.08)</td>
</tr>
<tr>
<td>ΔE</td>
<td>0.08 (0.74)</td>
<td>0.09 (0.71)</td>
<td>0.13 (0.6)</td>
</tr>
</tbody>
</table>

Significance in brackets.
ments provide a significantly better color match to the un-restored neighboring teeth than porcelain-fused-to-metal restorations on titanium or gold abutments. Unfortunately, no specification on the number of gold or titanium abutment nor a description on the possible different outcome present between these two types of abutment has been made. Moreover, considering the properties of zirconium oxide vs. aluminum oxide, zirconium oxide should be referred on implant-supported restorations [Butz et al. 2005; Canullo, 2007; Garine et al. 2007].

Another in vitro study by [Jung et al. 2007] reported a decrease of the color change related to an increasing of the mucosa thickness over zirconia and titanium. In situations with a mucosal thickness of 1.5 mm, both materials demonstrated ΔE values above the critical threshold of 3.7 [Park et al. 2007], with a score of 3.87 for zirconium oxide and 5.06 for titanium. With a mucosa thickness of 2 mm, the color change induced by zirconia was below the threshold of 3.7 (3.17), whereas titanium still caused a visible difference (4.32). With a 3 mm thickness, all the abutments scored within the limit of 3.7 (titanium 2.14 and zirconia 2.47).

For this reason, the present study also tried to assess possible in vivo implication of the thickness of peri-implant mucosa by dichotomizing it at 2 mm: 7 patients with thin and 13 with thick peri-implant soft tissues were observed. As shown on Table 4, no statistically significant differences were present in the color of the mucosa between thick and thin tissue. Even if a trend of higher values of differences was noticed, especially with titanium abutment, in the thick group, this study did not confirm that mucosa thickness mucosa is a crucial factor in terms of discoloration as concluded by [Jung et al. 2007]. Most probably this result differed from the previous literature due to the reduced sample size. Another reason for this trend could be that no soft tissue thickness ≥ 3 mm was found in the group classified as “Thick.” Further researches on more representative patient samples are requested to confirm or refuse this trend.

Regarding an eventual shortcoming of the thickness measurement by means of a caliper applied to the study cast, the authors considered that a customized pick-up was able to permit a precise reproduction of the trans-mucosal soft tissue cone, and a light-consistence polyether material could not interfere in the soft tissue thickness re-production. Probably, the subsequent step of the gingival re-construction on the master cast by means of a siliconic material could add some degree of inaccuracy (maybe fraction of millimeter) in the peri-implant mucosa re-production. It could be interesting to compare the accuracy of this method with that used by [Sailer et al. 2000] and [Zembic et al. 2009]. They recorded the soft tissue thickness in the region of esthetic assessment both at implants and teeth using an endodontic file (ISO #20) with a rubber stop.

Conclusions

Within the limitation of the present study, the following conclusions can be drawn:

- the peri-implant soft tissue color is different from the soft tissue color around natural teeth, no matter which type of restorative material is selected.
- titanium abutments are associated with significantly higher differences than those obtained with gold or zirconia abutments.
- no significant differences are present between the color of peri-implant soft tissue around zirconia abutment and the one around gold abutment.
- the thickness of the peri-implant soft tissue does not appear to be a crucial factor in the abutment impact on the soft tissue color.

References


**Supporting Information**

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Supporting information in accordance with the CONSORT Statement 2001 checklist used in reporting randomized trials.

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